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Original Article

A prospective study of sleep problems in children with ADHD

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ABSTRACT

Background: Behavioral sleep problems are common in children with attention-deficit/hyperactivity disorder (ADHD), yet their persistence or otherwise is unknown. We examined behavioral sleep problem trajectories, types of sleep problems experienced, and associated risk/protective factors.
Methods: Design: Prospective cohort study. *Setting:* Twenty-one pediatric practices across Victoria, Australia. *Participants:* A total of 195 children with ADHD (5–13 years). *Outcomes:* Sleep problem trajectories classified as never, transient, or persistent on the basis of sleep problem severity measured at baseline, 6, and 12 months. *Explanatory variables:* Types of sleep problems, internalizing and externalizing comorbidities, ADHD symptom severity and medication use, autism spectrum disorder, caregiver mental health, and sociodemographic factors. *Analyses:* Multinomial logistic regression models.
Results: Sleep problems fluctuated over 12 months, but for 10% of children they persisted. In adjusted analyses, co-occurring internalizing and externalizing comorbidities were a risk factor for persistent (odds ratio (OR) 9.2, 95% confidence interval (CI) 1.6, 53.9, $p = 0.01$) and transient (OR 3.7, 95% CI 1.5, 8.8, $p = 0.003$) sleep problems, while greater ADHD symptom severity and poorer caregiver mental health were risk factors for persistent and transient sleep problems, respectively.
Conclusions: Sleep problems in children with ADHD are commonly transient, but in a subgroup they are characterized as persistent. Early preventive/intervention strategies should target children at risk of persistent sleep problems.

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1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) affects 5% of children worldwide [1], and these children are two to three times more likely to experience sleep problems compared with their typically developing peers [2,3]. Children with ADHD commonly experience sleep problems such as sleep-onset delay, bedtime resistance, and night awakenings [4,5]. These problems are usually behavioral in nature (i.e., thought to originate from a non-biological cause) but can also be the result of undiagnosed biological sleep problems (e.g., restless legs syndrome or sleep disordered breathing) [6], which are also more common in children with ADHD, compared with typically developing children [7,8]. Sleep problems in children with ADHD are associated with poorer daily functioning [5] and while they have long been recognized in this group [9,10], their persistence or otherwise remains largely unknown. Longitudinal data are required to establish sleep problem trajectories in children with ADHD, which can inform clinicians about their prognosis. Identifying which child/family factors and types of sleep problems put children at risk of persistent sleep problems would also allow for better targeting of early intervention and prevention efforts.

In typically developing children, sleep problems have been shown to be largely transient. A population-based study of children ($n = 4460$) showed that 13% of children aged 4–5 years had moderate/severe sleep problems by parent report, yet two years later sleep problems persisted in only 3% [11]. This picture appears more complicated for children with mental health difficulties [12] and neurobehavioral disorders such as ADHD [3]. The strong neurological overlap between the structures involved in ADHD and sleep are likely to play a contributing role to elevated sleep problems in this group [3,13]. However, only two longitudinal studies to date have

Abbreviations: ADHD, Attention-deficit/hyperactivity disorder; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders IV; ADIS-C, Anxiety Disorders Interview Schedule for Children/Parent, IV; CSHQ, Children's Sleep Habits Questionnaire; RCT, Randomized Controlled Trial; SEIFA, Socio-Economic Indexes for Areas; DASS, Depression Anxiety Stress Scale; SD, Standard deviation; OR, Odds ratio.

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examined sleep problems in children with ADHD. In a clinical sample (7–13 years, $n = 76$), 72% of sleep problems persisted from baseline to 18 months in children with ADHD and/or anxiety. Child age and gender, parent education level, and total number of stressful life events did not predict sleep problems 18 months on but sleep problems at baseline did [14]. These findings are limited in how they generalize to children with ADHD managed by clinicians because of the inclusion of children with anxiety only and exclusion of children taking ADHD medication [15]. Children with ADHD have also been shown to have shorter sleep duration than children without ADHD by parent report from birth to 11 years, and this was statistically significant at ages 5.9, 6.9, and 9.7 years [16]. Yet, this study did not examine the persistence of sleep problems per se over time.

Cross-sectionally, sleep problems in children with ADHD have been associated with greater ADHD symptom severity [5,17,18]; ADHD medication [19–21]; internalizing [17,22,23] and externalizing comorbidities [18,23], in particular when they co-occur [24]; and poorer parental mental health [5]. Yet, the cross-sectional nature of these studies makes it impossible to delineate whether these factors are predictors or consequences of sleep problems. Thus, longitudinal data are required to identify risk factors for sleep problem trajectories.

We therefore aimed, in a large, multisite sample of children with ADHD, to examine:

1. behavioral sleep problem trajectories over a 12-month period,
2. types of sleep problems experienced, and
3. risk and protective factors for sleep problem trajectories.

2. Methods

2.1. Design and setting

This longitudinal study draws on data collected across three time points – baseline, 6, and 12 months – from two harmonized studies. All participants were recruited from the same sampling frame – 21 public and private pediatric practices across Victoria, Australia. Children with moderate/severe behavioral sleep problems at baseline were enrolled in a randomized control trial (RCT) [25] of a behavioral sleep intervention, while those with no/mild sleep problems were enrolled in a cohort study [26]. Children in the intervention arm of the RCT were excluded from the present study as it was highly likely the sleep intervention would have altered their sleep trajectories.

2.2. Eligibility and recruitment

Pediatricians sent "opt-out" letters to patients with an ADHD diagnosis, aged between 5 and 12 years, who had attended an appointment within the past 12 months. If families did not "opt out," the pediatrician passed their contact details on to the research team. The study was approved by The Royal Children's Hospital Melbourne Human Research Ethics Committee (30033; 28017) and the Victorian Department of Education and Early Childhood Development (000573; 001307).

2.2.1. Inclusion criteria

Children were eligible if they had a previous ADHD diagnosis, were aged 5–13 years at the time of the recruitment, and met the Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition (DSM-IV) criteria for ADHD [27], which was assessed using the ADHD Rating Scale IV (rated off medication) [28], and study-specific questions assessing age of onset, symptom duration, and cross-situational impairment. Children had to meet six of nine criterion for each of the inattentive and/or hyperactive/impulsive symptoms and the three study-specific questions in order to be eligible; this measure was used to define the ADHD subtype. Caregivers also had to be able to report on the child's sleep problem severity over the past 4 weeks (not a problem, or a mild, moderate, or severe problem; see Measures below). If a moderate/severe sleep problem was reported, further specific questions were asked to ensure the child met the American Academy of Sleep Medicine criteria for at least one behavioral sleep problem [29].

2.2.2. Exclusion criteria

The exclusion criteria included the following: (1) a major illness (e.g., cerebral palsy) or intellectual disability (i.e., IQ <70), which may influence sleep trajectories; (2) insufficient English to participate due to study resource limitations; (3) seeking help from a health professional for the child's sleep problem from someone aside from the pediatrician (e.g., psychologist or sleep clinic) – an important criteria to determine inclusion for the RCT sample; and (4) screening positive for obstructive sleep apnea (assessed using the Children's Sleep Habits Questionnaire or CSHQ) [30] – a common sleep problem in children with ADHD that is not behavioral in nature.

2.3. Procedures

Families that did not "opt out" were telephoned by the research team to assess eligibility. Eligible families were sent a baseline survey, information statement/consent form, and a reply paid envelope. Upon receipt of the survey and signed consent form, families were enrolled. Researchers then telephoned caregivers to complete a diagnostic phone interview to assess child internalizing and externalizing comorbidities (see "Measures"). At 6 and 12 months post enrollment, families were sent a follow-up survey. Data collection took place between 2010 and 2013.

2.4. Measures

2.4.1. Child sleep problem

This was assessed at baseline, 6, and 12 months by asking caregivers "*Has your child's sleep been a problem for you over the past 4 weeks?*" If "yes," caregivers were asked to rate the severity of the problem as mild/moderate/severe [31]. This measure has been widely used in children with and without ADHD and been shown to dichotomize children into two distinct sleep problem groups: no/mild versus moderate/severe [5,11,31]. Furthermore, moderate/severe sleep problems have been associated with poorer child and parental well-being [5,11], as well as poorer classroom behavior reported by teachers blinded to sleep problem severity [11]. Therefore, moderate/severe sleep problems were defined as a "sleep problem" and no/mild as "no sleep problem."

2.4.2. Type of sleep problems

This was assessed using the CSHQ – a validated 33-item measure, where higher scores are more problematic. The CSHQ distinguishes samples of children attending a sleep clinic from a community sample [30]. Eight sleep problem domains were examined (bedtime resistance, sleep duration, parasomnias, night waking, daytime sleepiness, sleep anxiety, sleep-onset delay, and sleep-disordered breathing), as well as total sleep problems and sleep duration. Internal consistency for sleep problem domains was reasonable to good in our sample (Cronbach's alpha (α) = 0.64–0.86).

2.4.3. Internalizing and externalizing comorbidities

These were assessed by the Anxiety Disorders Interview Schedule for Children/Parent Version IV – a diagnostic interview that for research purposes provides reliable diagnoses according to

DSM-IV [32] and yields excellent to acceptable 7–14-day test–retest reliability ($k = 0.65–1.00$) [33]. Trained research assistants administered the interview to the child's caregiver via telephone interview. Although researchers were unblind to the child's sleep problem severity, a cross-scoring of 6% of interviews showed that inter-rater reliability was excellent for 10 of the 11 disorders ($k = 0.83–1.0$; $p < 0.001$) with good reliability ($k = 0.69$; $p < 0.001$) for obsessive compulsive disorder.

Eleven disorders were assessed [24]. To endorse a disorder, the symptoms needed to cause significant impairment (rated ≥4 on a 0–8 scale). Children with two or more anxiety disorders or a mood disorder were classified as having an internalizing comorbidity – this classification results in high sensitivity and specificity for detecting internalizing comorbidities in children with ADHD [34], while an externalizing comorbidity was classified as an oppositional defiant or conduct disorder. Children were also classified into one of four comorbidity categories: none, internalizing alone, externalizing alone, and co-occurring internalizing and externalizing.

2.4.4. ADHD symptom severity

This was assessed using the ADHD Rating Scale IV – an 18-item validated scale measuring core ADHD symptoms (i.e., inattention and impulsivity/hyperactivity) [28]. Caregivers were asked to rate usual behavior (i.e., while on medication if this was usual).

2.4.5. Autism spectrum disorder

Caregivers were asked to report whether their child had ever been diagnosed with autism spectrum disorder (ASD) by a health professional.

2.4.6. ADHD medication use

Caregivers were asked whether their child takes medication for ADHD. In Australia, this includes short- and long-acting methylphenidate, dexamphetamine, and atomoxetine.

2.4.7. Caregiver mental health

This was assessed using the Depression Anxiety Stress Scale (DASS) – a 21-item measure of adult mental health where higher scores indicate poorer mental health [35].

We also collected data on child age and gender, caregiver age and education level, and family neighborhood socioeconomic disadvantage – measured by the census-based Socio-Economic Indexes for Areas Disadvantage Index (SEIFA) for the child's postcode of residence (national mean 1000, standard deviation (SD) 100; higher scores reflect less disadvantage) [36]. In addition, at 6 and 12 months, parents were also asked whether they had sought help for their child's sleep since joining the study.

2.5. Analyses

Inclusion in longitudinal analyses required data at *all* three time points. Analyses were conducted using Stata 12.0 (Stata Corp, College Station, TX, USA).

For Aim 1 (*sleep trajectories over 12 months*), descriptive statistics classified children into sleep problem trajectories based on dichotomized sleep problem status across the three time points. Four sleep problem trajectories were anticipated: (1) never, (2) remitted, (3) incident, and (4) persistent.

For Aim 2 (*types of sleep problems experienced*), the summary measures for each sleep problem domain, as well as total sleep problems and sleep duration, were created by averaging scores across all three time points [37]. The mean differences in these summary scores according to the sleep problem trajectory were estimated using univariate linear regression models.

For Aim 3 (*risk and protective factors for sleep trajectories*), each trajectory was entered as a nominal outcome in multinomial logistic regression models to examine the associations between risk and protective factors and sleep problem trajectories. Results represent a comparison of the odds of experiencing a problematic sleep trajectory rather than the "never" (reference) trajectory according to each risk factor. Single risk factors with a p value <0.1 were then included in a multiple-variable model (with $p < 0.1$ chosen rather than the more conservative $p < 0.05$ to avoid excluding potentially important confounders).

3. Results

3.1. Recruitment and follow-up

We assessed 827 children for eligibility, of whom 561 were eligible and 392 (70%) enrolled (see Fig. 1). Enrolled children were comparable to those who chose not to participate based on child age, gender, and family socioeconomic status.

Of the 392 enrolled children, (148 with no/mild (cohort study) and 244 with moderate/severe sleep problems (RCT)), 122 were excluded as they were allocated to the intervention arm of the RCT, which left 270 children for this longitudinal study. Sleep problem severity data were available for 229 (85%) and 207 (77%) children at 6 and 12 months, respectively. Data were available at *all* three time points for 195 (72%) children, and these children were comparable to those without data at all time points in terms of child age, gender, ADHD symptom severity, internalizing and externalizing comorbidities, and SEIFA scores.

3.2. Sleep problem trajectories (Aim 1)

Sleep problem severity fluctuated over the 12-month period (Fig. 2). We anticipated four sleep problem trajectories; yet, upon inspection of sleep problem timing and persistence, a decision was made to combine the two transient groups (remitted and incident) to allow a more substantive group for meaningful analysis. Thus, three groups were defined: (1) "never" (no sleep problem at any point), (2) "transient" (sleep problem at one or two points), and (3) "persistent" (sleep problem at all three points). The most common trajectory was transient (49%; 95% CI 42, 56), followed by never (41%; 95% CI 34, 48) and persistent (10%; 95% CI 6, 15).

Sample characteristics are described in Table 1. The children were on average 10 years old (range: 5–13 years), male, and taking ADHD medication. Primary caregivers were predominately mothers of whom 52% had completed high school. Across sleep problem trajectories, child gender and age, ASD, and caregiver age appeared relatively similar, whereas ADHD medication use, ADHD symptom severity and subtype, and co-occurring internalizing and externalizing were more common moving from never to transient to persistent sleep problems trajectories.

At 6 and 12 months, 22% and 25% of parents reported seeking help for their child's sleep since entering the study, respectively. Seeking help at either 6 or 12 months varied across the never (8%), transient (36%), and persistent (35%) trajectories ($p < 0.001$). Of those that sought help, the most frequent source was the child's pediatrician (90%).

3.3. Types of sleep problems (Aim 2)

All sleep problem domain scores were higher in the transient and persistent sleep problem trajectories relative to the children never experiencing sleep problems (Table 2). The sleep problem scores differed statistically for all domains except sleep-disordered breathing – where scores were all low (noting this was an exclusion criteria). The children's sleep duration ranged from 10.0 h in the never trajectory to 9.0 and 8.0 h in the transient and persistent trajectories, respectively.

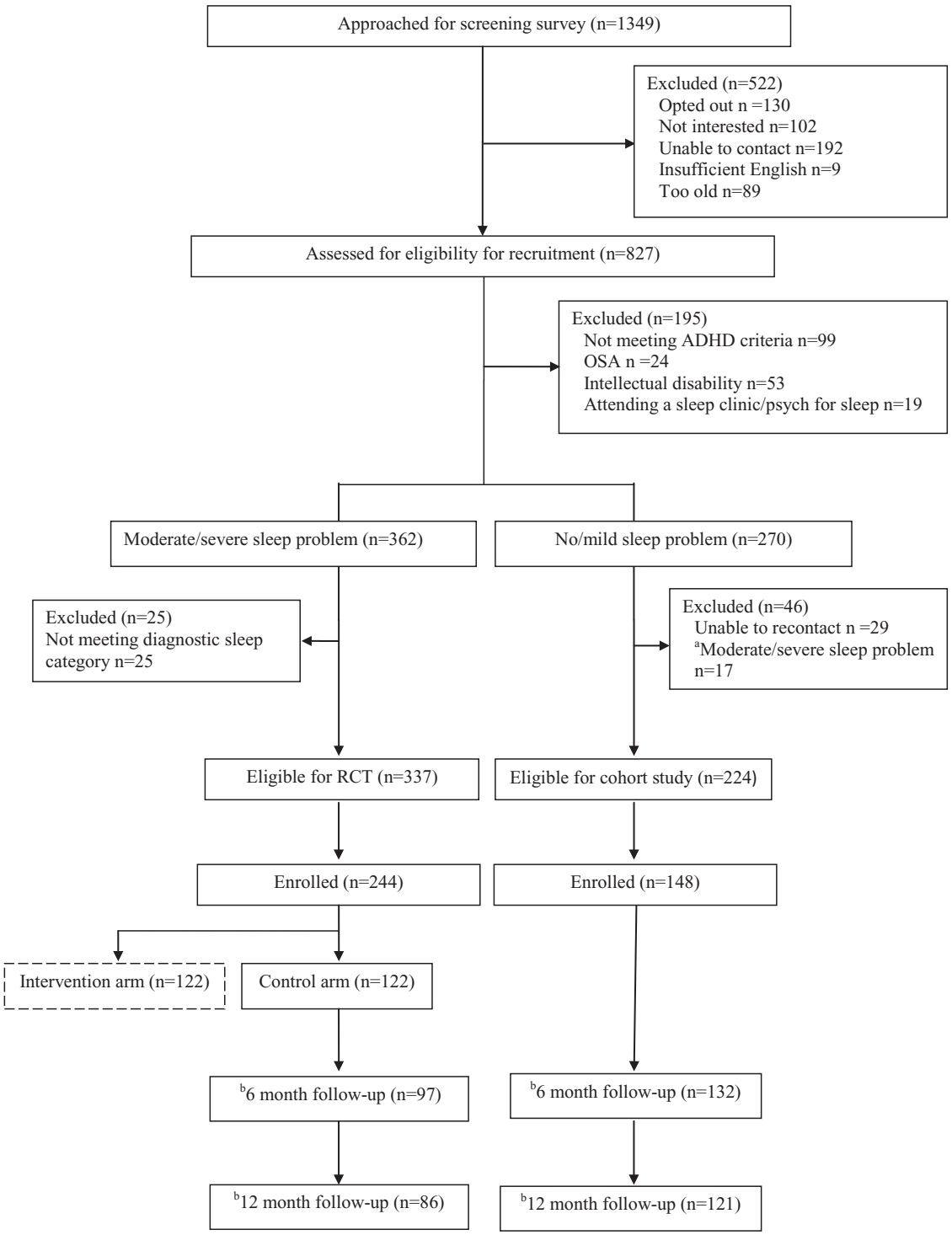

Fig. 1. Participant Flow. [a] RCT recruitment finished 6 months earlier than the cohort study; thus, these 17 children were ineligible. [b]Children with sleep problem severity data available at the 6- and 12-month follow-up.

3.4. Risk and protective factors for sleep problem trajectories (univariate analyses)

The presence of co-occurring internalizing and externalizing comorbidities was associated with 5.1-fold (95% CI 2.2, 11.7, $p < 0.001$) and 24.2-fold (95% CI 2.8, 210.2, $p = 0.004$) higher odds of transient and persistent sleep problems, respectively (Table 3). Similarly, each SD-unit-higher ADHD symptom severity was associated with 1.4-fold (95% CI 1.0, 2.0, $p = 0.03$) and 3.8-fold (95% CI 2.0, 7.3, $p < 0.001$) higher odds of transient and persistent sleep problems, respectively. Externalizing comorbidity alone and ADHD medication use were only associated with higher odds of persistent sleep problems (odds ratio (OR) 10.7 95% confidence interval (CI) 1.2, 93.9, $p = 0.03$ and OR 6.0 95% CI 0.8, 48.0, $p = 0.09$, respectively).

Primary caregiver characteristics were also associated with sleep problem trajectories. Each SD-higher total DASS score (i.e., poorer

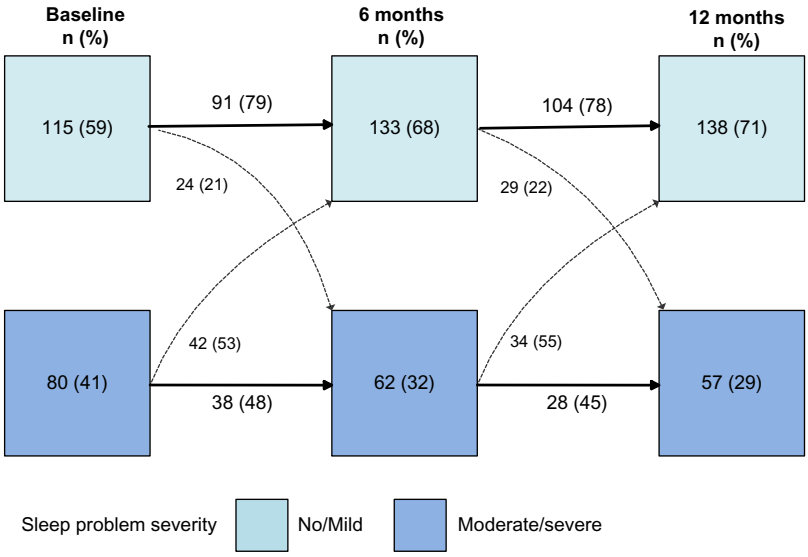

Fig. 2. Patterns of occurrence and resolution of sleep problems in children with ADHD over 12 months.

mental health) was associated with 1.9-fold (95% CI 1.3, 2.8, $p = 0.001$) higher odds of children experiencing transient sleep problems. Yet, each 100 point (i.e., one SD unit) higher SEIFA (i.e., less disadvantage) was associated with 0.7-fold (95% CI 0.5, 1.0, $p = 0.04$) and 0.6-fold (95% CI 0.3, 0.9, $p = 0.02$) lower odds of transient and persistent sleep problems, respectively. This was also true for high school completion and transient sleep problems (OR 0.4 95% CI 0.2, 0.8, $p = 0.008$) with some evidence of an effect for persistent sleep problems (OR 0.6 95% CI 0.3, 0.9, $p = 0.06$). These single-child and caregiver factors were included in a multiple-variable model to examine their combined association with sleep problem trajectories.

3.5. Risk and protective factors for sleep problem trajectories (multiple variable models)

The presence of co-occurring internalizing and externalizing comorbidities was the strongest risk factor for transient (OR 3.7, 95% CI 1.5, 8.8, $p = 0.003$) and persistent (OR 9.2, 95% CI 1.6, 53.9, $p = 0.01$) sleep problems. ADHD symptom severity was associated with persistent sleep problems only (OR 2.7 95% CI 1.3, 5.3, $p = 0.006$). ADHD medication use was also associated with persistent sleep problems (OR 8.4 95% 1.0, 74.2, $p = 0.05$), while poorer parental mental health was associated with higher

Table 1
Baseline characteristics by sleep trajectory group.

	Total	Sleep problem trajectory groups, *n* (%)		
	N (%) 195 (100)	Never 79 (41)	Transient 96 (49)	Persistent 20 (10)
Child				
Male, %	87.2	86.1	89.6	80.0
Age in years (mean (SD))	10.1 (1.9)	10.4 (1.5)	10.0 (2.0)	9.7 (2.4)
Medication for ADHD, %	78.5	76.0	77.1	95.0
Psychostimulants[a]	73.9	70.9	72.9	90.0
Atomoxetine	5.6	7.6	4.2	5.0
Autism spectrum disorder, %	26.7	21.5	31.3	25.0
ADHD symptoms (mean (SD))	34.8 (10.1)	32.0 (9.5)	35.4 (9.7)	43.2 (9.3)
ADHD subtype, %				
Inattentive	34.4	45.6	28.1	20.0
Combined	59.5	45.6	66.7	80.0
Hyperactive/Impulsive	6.2	8.9	5.2	0.0
Internalizing, externalizing comorbidities, %				
None	26.8	36.7	23.2	5.0
Internalizing alone	16.0	24.1	10.5	10.0
Externalizing alone	22.2	24.1	17.9	35.0
Co-occurring internalizing and externalizing	35.1	15.2	48.4	50.0
Primary caregiver				
Mother, %	94.3	94.9	93.7	94.7
Age in years (mean (SD))	41.2 (6.2)	41.2 (5.2)	40.8 (6.4)	43.8 (8.4)
Completed high school, %	51.6	64.1	43.8	40.0
DASS total score (mean (SD))[b]	31.1 (23.7)	23.9 (17.5)	36.9 (27.2)	31.1 (19.3)
Family				
SEIFA (mean (SD))[c]	1004.1 (62.6)	1017.6 (58.9)	997.9 (57.8)	981.1 (86.6)

[a] Psychostimulants were defined as taking methylphenidate, dexamphetamine.
[b] DASS, Depression Anxiety Stress Scale.
[c] SEIFA, Socio-Economic Indexes for Areas (i.e., higher score indicates less disadvantage); SD, standard deviation.

Table 2
Average sleep problem domain scores across the three time points by sleep trajectories.

Sleep problem domain (possible range; community sample mean (SD))[a]	Total	Sleep problem trajectory groups, *n*			p value[b]
	N 195	Never 79	Transient 96	Persistent 20	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Bedtime resistance (6–18; 7.1 (1.9))	8.0 (2.3)	7.0 (1.7)	8.3 (2.0)	10.7 (3.5)	<0.001
Sleep duration (3–9; 3.4 (0.9))	5.0 (1.4)	4.1 (1.1)	5.5 (1.1)	7.0 (0.8)	<0.001
Parasomnias (7–21; 8.1 (1.3))	10.3 (2.2)	9.5 (1.7)	10.5 (2.2)	12.2 (2.8)	<0.001
Night waking (3–9; 3.5 (0.9))	4.3 (1.3)	3.7 (0.8)	4.5 (1.3)	5.6 (2.0)	<0.001
Daytime sleepiness (8–24; 9.6 (2.8))	14.2 (3.6)	13.3 (3.3)	14.6 (3.6)	15.2 (4.5)	0.03
Sleep anxiety (4–12; 4.9 (1.5))	5.9 (1.9)	5.1 (1.4)	6.2 (1.8)	8.0 (2.4)	<0.001
Sleep onset delay (1–3; 1.3 (0.5))	2.1 (0.6)	1.8 (0.6)	2.3 (0.6)	2.7 (0.4)	<0.001
Sleep disordered breathing (3–9; 3.2 (0.6))	3.7 (0.8)	3.6 (0.8)	3.7 (0.8)	3.9 (1.0)	0.32
Total problems (32–96; 56.2 (8.9))	50.9 (8.9)	45.8 (6.8)	53.0 (7.7)	61.9 (8.9)	<0.001

SD, standard deviation.
[a] Reference data from a community sample ($n = 469$ aged 4–10 years) [28].
[b] *p* values calculated using univariate linear regression.

odds (OR 1.5 95% CI 1.0, 2.3, $p = 0.05$) of transient sleep problems (Table 3).

4. Discussion

This is the first large, prospective cohort study to examine sleep problem trajectories and their risk factors in children with ADHD. While the majority of sleep problems were transient over a 1-year period, they persisted in 1 in 10 children. A diversity of sleep problems was experienced by children in both the transient and persistent trajectories. Risk factors for persistent sleep problems include co-occurring internalizing and externalizing comorbidities, ADHD medication use and greater ADHD symptom severity. Risk factors for transient sleep problems include co-occurring internalizing and externalizing comorbidities and poorer parental mental health.

The largest group was that of children with transient sleep problems (49%) over a 12-month period. Clinically, this highlights the importance of examining sleep across repeated clinical consultations and suggests that fluctuation in sleep problems should be considered when examining treatment efficacy over time. Furthermore, the types of sleep problems experienced by children with problematic trajectories appear diverse. Thus, interventions should cover management techniques for a range of sleep problems. For example, shortened sleep duration (which negatively impacts daily functioning) may require behavioral therapies such as teaching parents to set limits around bedtime (for limit setting disorder) or manage anxiety with visual imagery and relaxation (for anxiety-related insomnia).

In children with ADHD and/or anxiety, Hansen et al. reported a greater persistence (72%) across two time points [14]. Our disparate persistence rates are likely explained by our classification of sleep problems at two time points as transient rather than persistent. We also looked at sleep over a shorter period (12 vs. 18 months) and our sample comprised fewer children with sleep problems at baseline (41% vs. 76%). Furthermore, all children in our sample had ADHD, whereas Hansen et al. also included children with anxiety only ($n = 30$), which is a known risk factor for child sleep

Table 3
Risk and protective factors for transient and persistent sleep problems.

Risk factors	Comparison of the odds of sleep problems			
	Transient ($n = 96$) vs. never ($n = 79$)		Persistent ($n = 20$) vs. never ($n = 79$)	
	OR[a] (95% CI)	p	OR[a] (95% CI)	p
Single variable models				
Internalizing and externalizing comorbidities				
Internalizing alone	0.7 (0.3, 1.8)	0.45	3.1 (0.3, 36.1)	0.38
Externalizing alone	1.2 (0.5, 2.8)	0.71	10.7 (1.2, 93.9)	0.03
Co-occurring internalizing & externalizing	5.1 (2.2, 11.7)	<0.001	24.2 (2.8, 210.2)	0.004
ADHD symptom severity (SD units)	1.4 (1.0, 2.0)	0.03	3.8 (2.0, 7.3)	<0.001
ADHD medication	1.1 (0.5, 2.1)	0.86	6.0 (0.8, 48.0)	0.09
Autism spectrum disorder	1.7 (0.8, 3.3)	0.15	1.2 (0.4, 3.8)	0.74
Gender	0.7 (0.3, 1.8)	0.48	1.5 (0.4, 5.5)	0.50
Age (SD units)	0.8 (0.6, 1.1)	0.14	0.7 (0.4, 1.1)	0.11
Caregiver completed high school (yes/no)	0.4 (0.2, 0.8)	0.008	0.4 (0.1, 1.0)	0.06
SEIFA (SD units)	0.7 (0.5, 1.0)	0.04	0.6 (0.3, 0.9)	0.02
Caregiver age (SD units)	0.9 (0.7, 1.3)	0.66	1.5 (0.9, 2.4)	0.10
Total DASS (SD units)	1.9 (1.3, 2.8)	0.001	1.5 (0.9, 2.7)	0.15
Multivariable model including risk factors of $p < 0.1$				
Externalizing alone	1.0 (0.4, 2.5)	0.92	3.7 (0.6, 23.1)	0.15
Co-occurring internalizing and externalizing	3.7 (1.5, 8.8)	0.003	9.2 (1.6, 53.9)	0.01
ADHD symptom severity (SD units)	1.1 (0.8, 1.6)	0.56	2.7 (1.3, 5.3)	0.006
ADHD medication	1.4 (0.6, 3.1)	0.42	8.5 (1.0, 74.2)	0.05
Caregiver completed high school (yes/no)	0.5 (0.3, 1.0)	0.06	0.5 (0.2, 1.5)	0.33
[b]SEIFA (SD units)	0.8 (0.5, 1.2)	0.23	0.7 (0.4, 1.9)	0.16
[c]Total DASS (SD units)	1.5 (1.0, 2.3)	0.05	1.1 (0.6, 2.1)	0.68

[a] Odds ratio and 95% confidence interval. The reference group being never having a sleep problem during the 12 months.
[b] SEIFA, Socio-Economic Indexes for Areas (i.e., higher score indicate less disadvantage).
[c] DASS, Depression Anxiety Stress Scale; SD, standard deviation.

problems. In congruence, we found that child age and gender were not risk factors for problematic sleep trajectories.

Our study has a number of strengths. Sleep was measured across three time points at six-month intervals, mirroring recommended pediatric clinical consultations in Australia [38]. Children were recruited from a diverse sampling frame with inclusive entry criteria (e.g., including ASD) to reflect a "real-world" sample and increase generalizability. Although our measure of child sleep problem severity was brief, it mapped directly onto the validated CSHQ. Furthermore, parent report is a valid screening measure of behavioral sleep problems that are likely to come to the attention of parents (e.g., sleep anxiety or bedtime resistance) [39]. We also used validated measures of ADHD (combined with a previous clinician diagnosis), internalizing and externalizing comorbidities, and parent mental health.

Our study also has some important limitations. Although it is a large study, the number of children in the persistent trajectory was small ($n = 20$), leading to insufficient power to demonstrate relationships precisely. In this instance, we have presented effect sizes along with their CIs reflecting the likely effects that are supported [40]. This may explain why some risk factors were only associated with transient sleep problems. Although four trajectories were anticipated, the "remitted" and "incident" categories were combined to represent a single transient category to ensure large enough groupings for meaningful analyses. Further research would be needed to examine whether risk factors differ between "remitted" and "incident" categories. The 12-month follow-up period was determined by the RCT and longer-term follow-up is required to establish sleep problem trajectories beyond this. The age range of children spanned 9 years; therefore, we were unable to examine age-specific sleep problem trajectories. Given the studies' focus on sleep, more families may have sought help for sleep compared to non-participants. If this is the case, then the true persistence of sleep problems may be higher – assuming seeking help for sleep translates into remission, which is not always the case [5]. Importantly, sleep medication (e.g., melatonin) data were not available at all three time points; thus, it is difficult to determine whether use of sleep medication altered trajectories. Our measure of ADHD medication combined psychostimulant and atomoxetine use, as there were very few children taking atomoxetine; future studies should investigate these separately to determine whether different types of ADHD medications have differential risks on sleep problem trajectories. Our measure of ASD is based on caregiver report of a previous diagnosis, which may have under-ascertained the true prevalence of ASD in our sample or incorrectly identified children as having ASD. Our findings are also limited to English speakers.

5. Conclusion

Sleep problems are usually transient in children with ADHD; however, in a subgroup of children, they tend to persist in the medium term. These findings flag children at risk and inform sleep problem trajectories in children with ADHD. Clinically, we recommend tracking sleep problems over time in children with ADHD with the brief screening question. Treating co-occurring internalizing and externalizing comorbidities may also hold promise for reducing sleep problems in children with ADHD and vice versa.

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Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2014.06.004.

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